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Kim et al.

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(54) **METHOD OF PROVIDING AN OPERATING VOLTAGE IN A MEMORY DEVICE AND A MEMORY CONTROLLER FOR THE MEMORY DEVICE**

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G11C 11/56 (2006.01)
G11C 16/10 (2006.01)

(52) **U.S. Cl.**

CPC **G11C 16/26** (2013.01); **G11C 11/5642** (2013.01); **G11C 16/0483** (2013.01); **G11C 16/10** (2013.01)

(58) **Field of Classification Search**

CPC G11C 16/0483; G11C 16/10; G11C 16/3418; G11C 11/5628; G11C 16/12
USPC 365/185.17–185.19, 185.23, 185.12
See application file for complete search history.

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Primary Examiner — David Lam

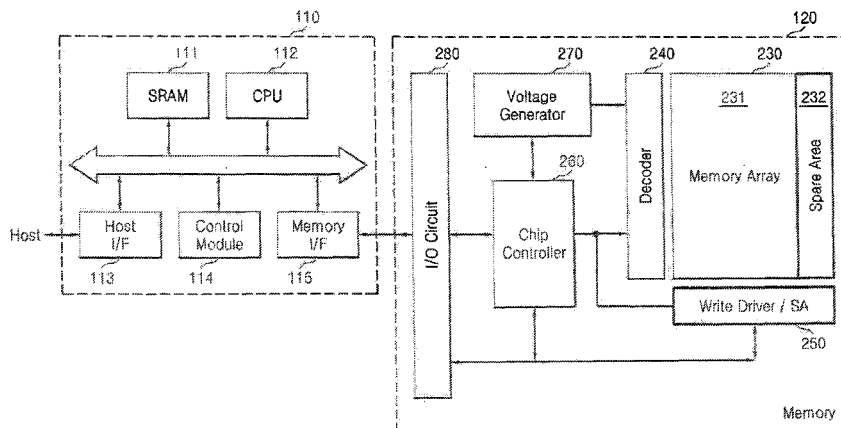
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(57)

ABSTRACT

A method of providing an operating voltage in a memory device includes applying a read voltage to a selected word line while applying a first pass voltage to at least one unselected word line among word lines adjacent to the selected word line; and while applying a second pass voltage to the remaining unselected word lines (other than the at least one unselected word line to which the first pass voltage is applied). The level of the first pass voltage is higher than the level of the second pass voltage. The level of the first pass voltage may be set based on the level of the read voltage.

20 Claims, 14 Drawing Sheets



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FIG. 1

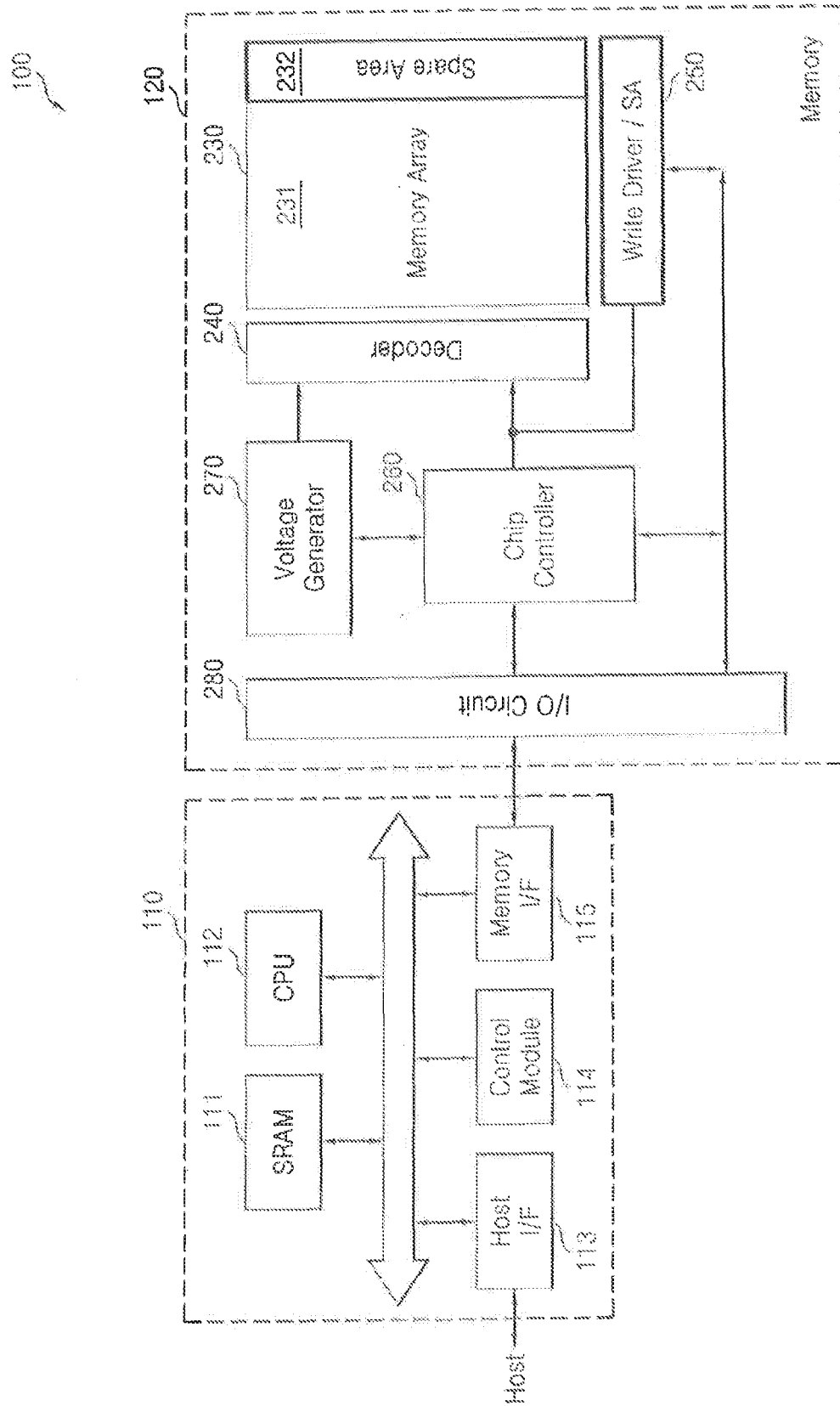


FIG. 2

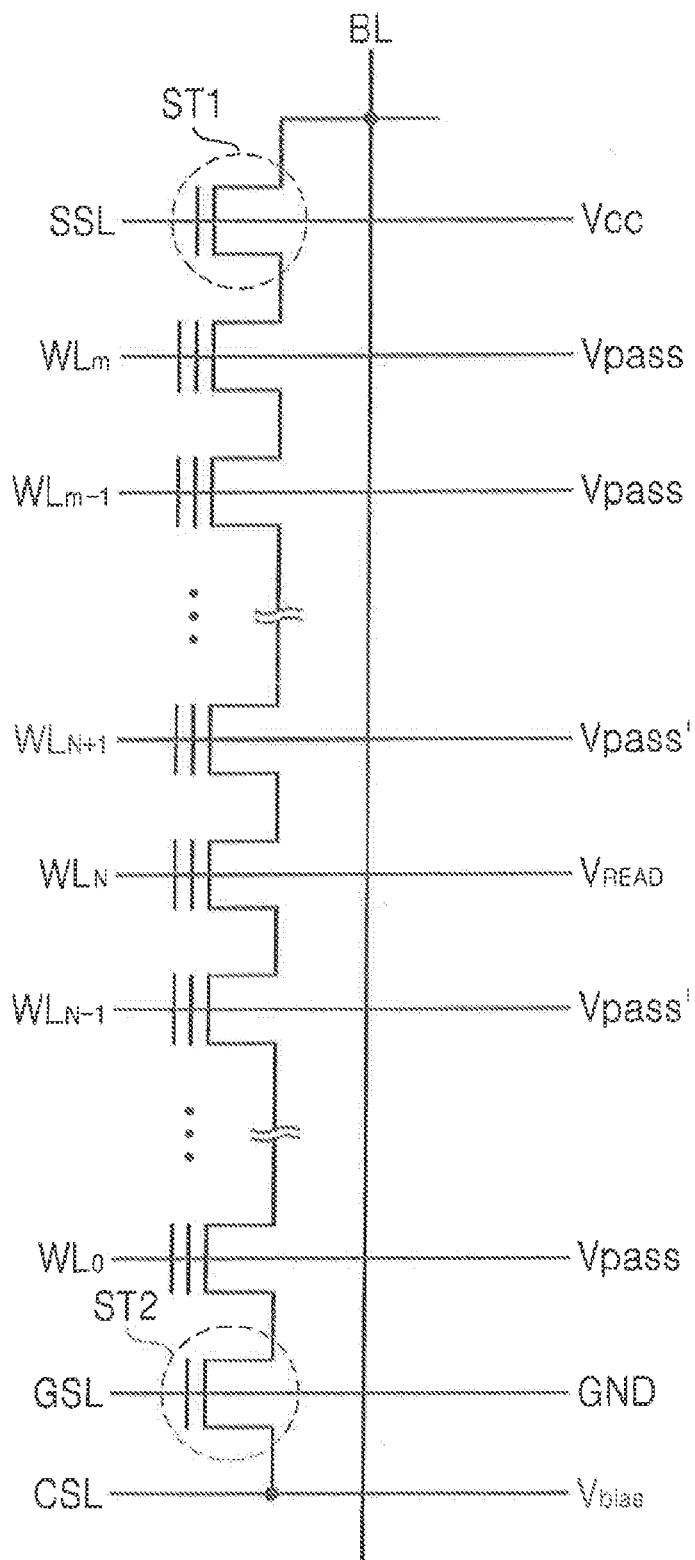


FIG. 3

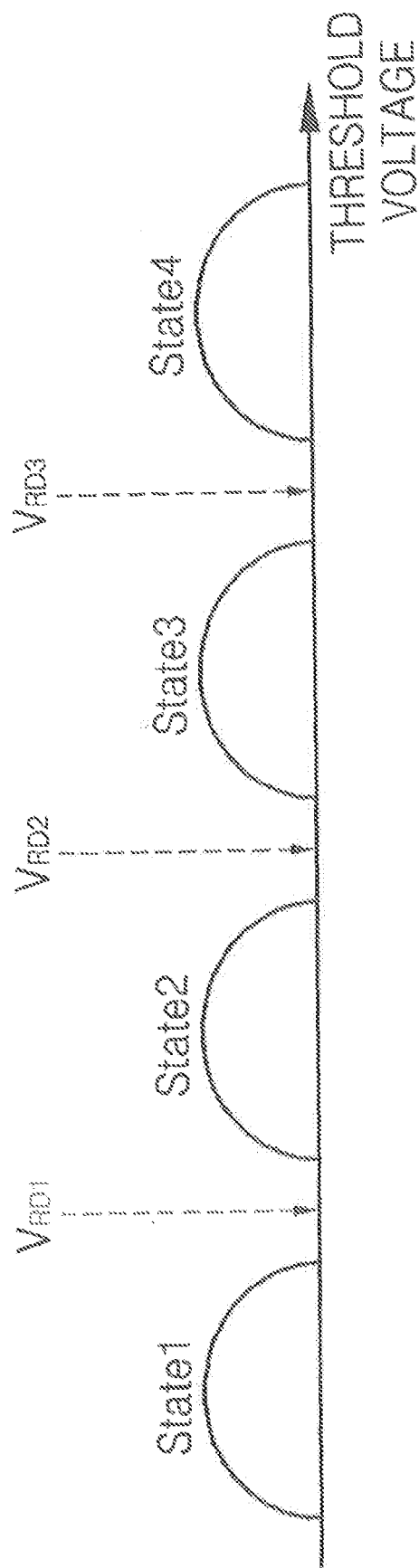


FIG. 4

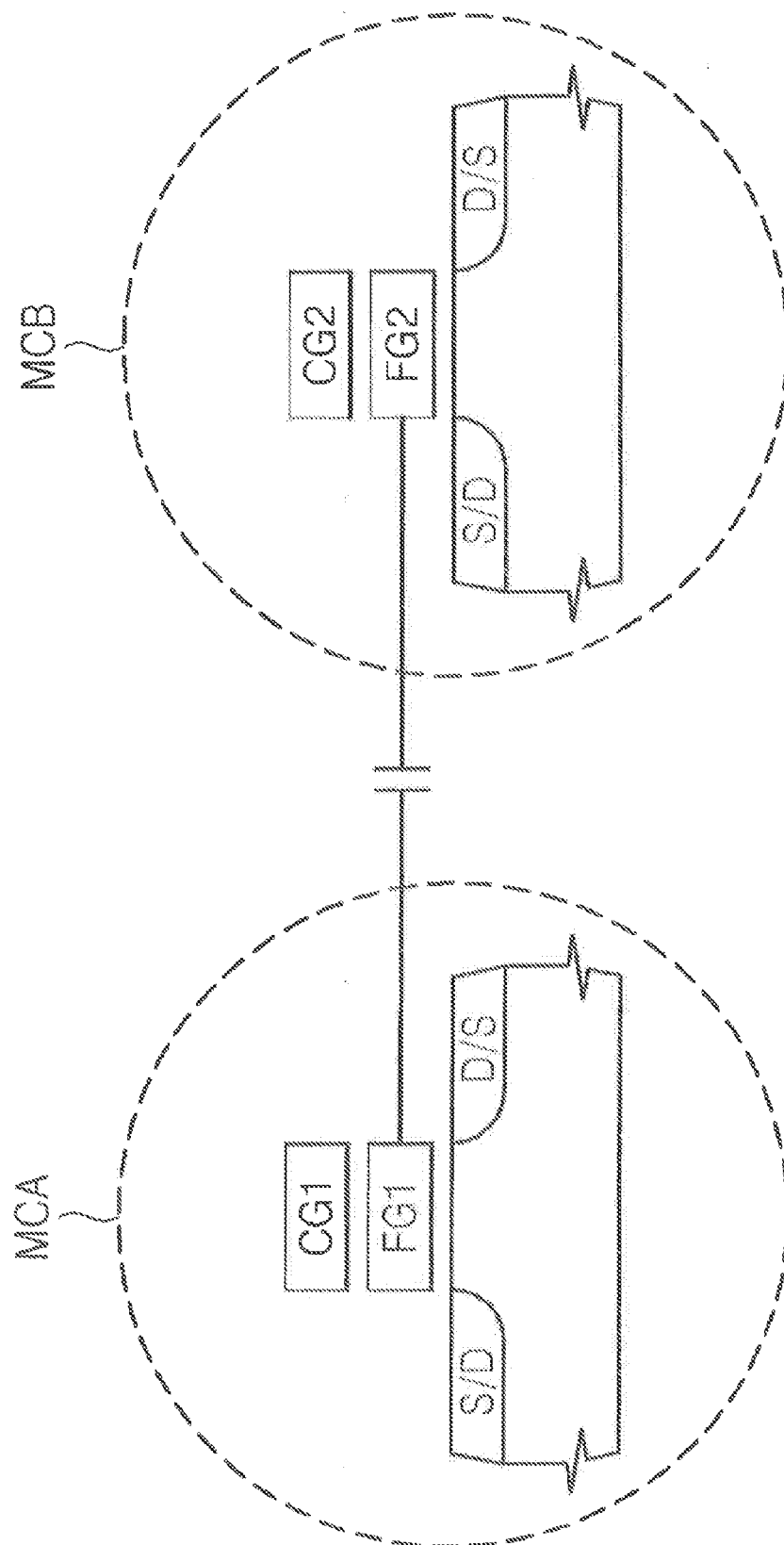


FIG. 5

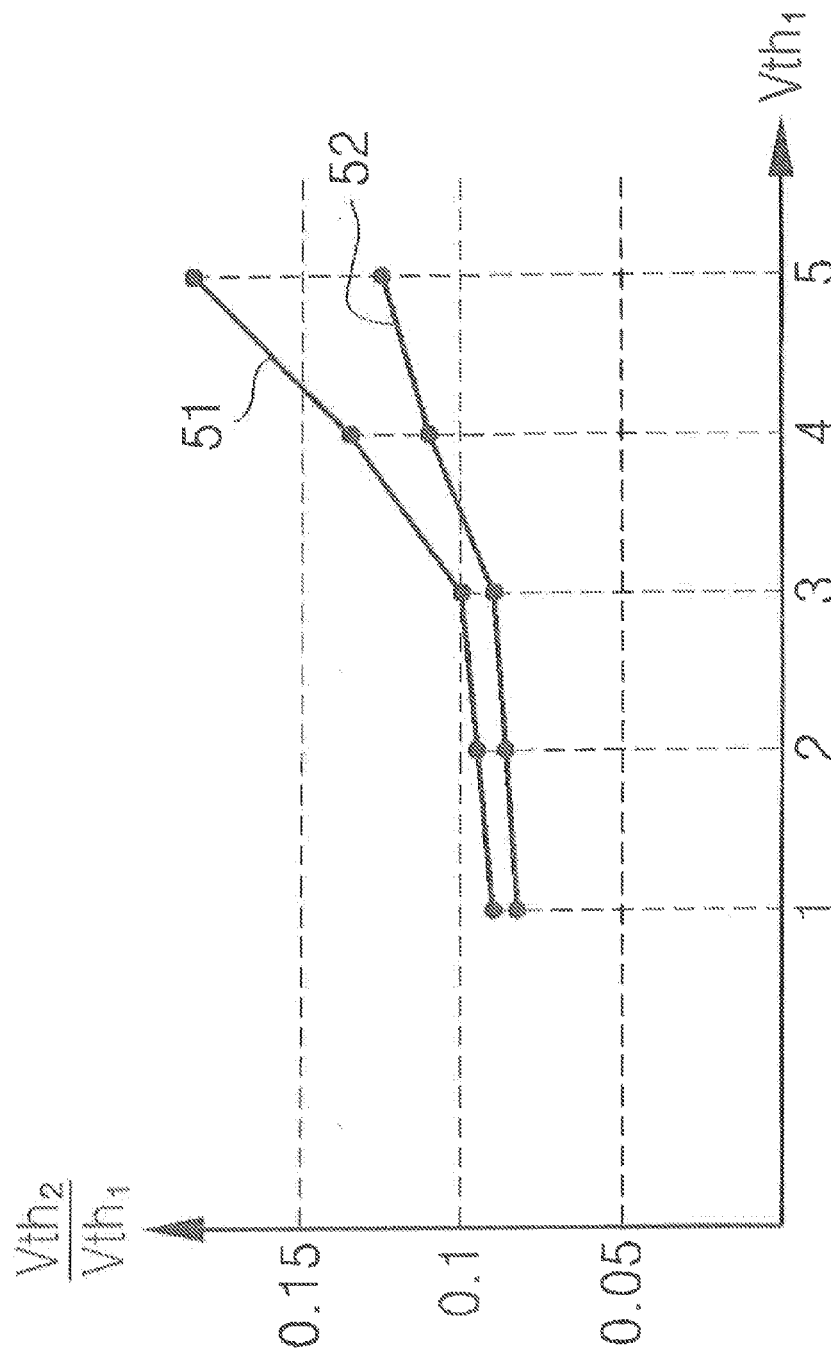


FIG. 6

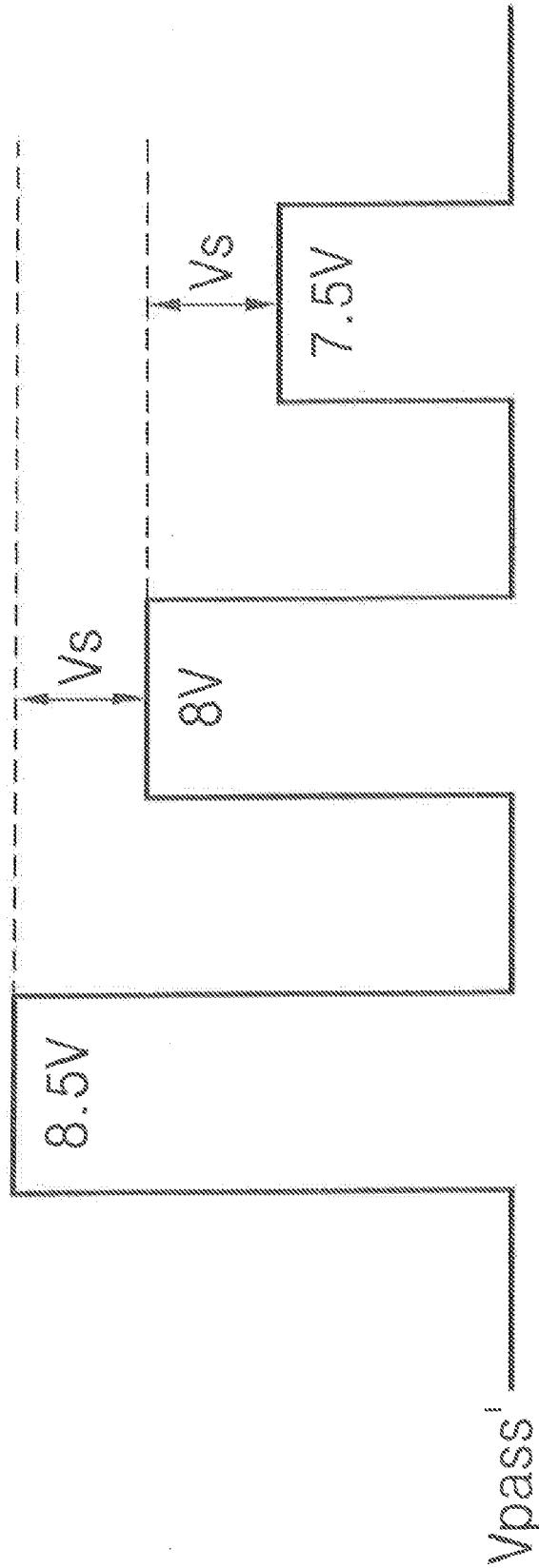


FIG. 7

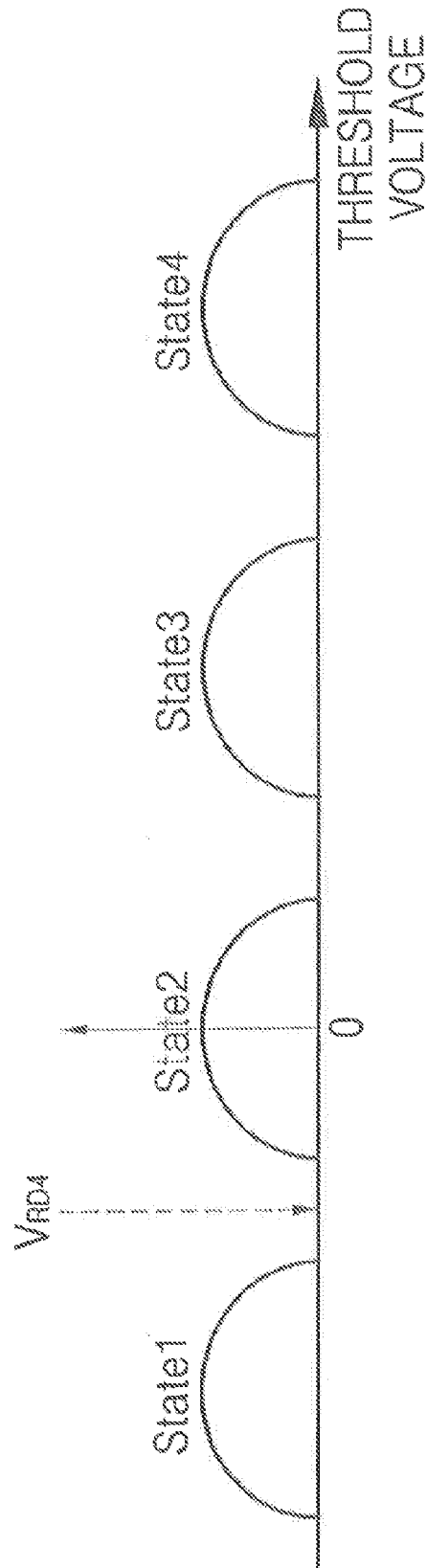


FIG. 8

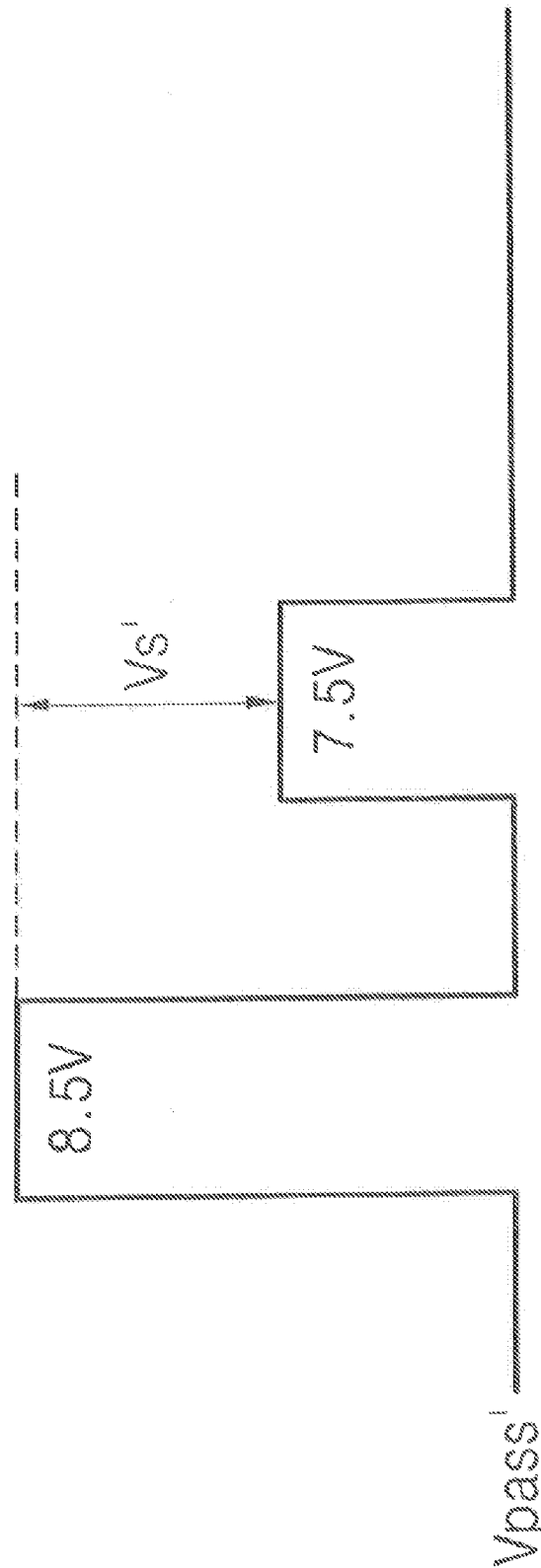


FIG. 9A

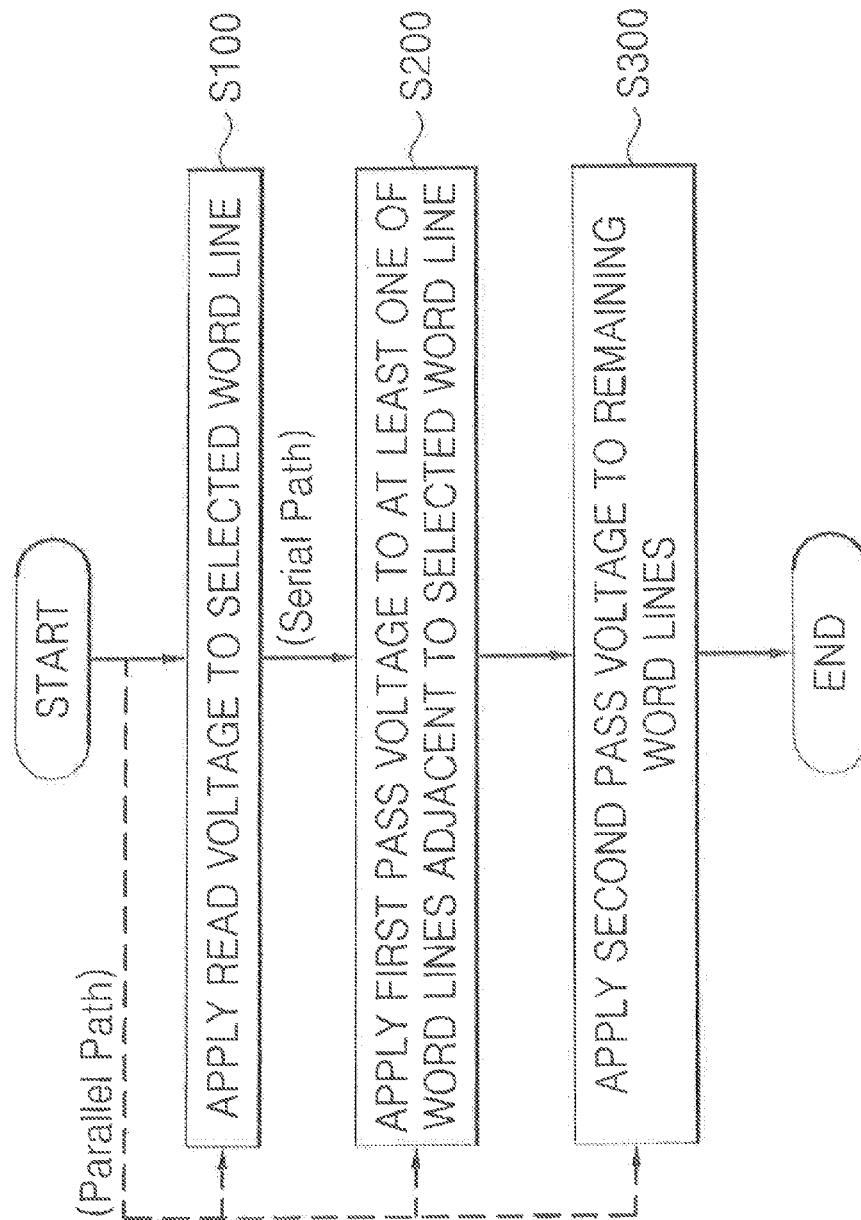


FIG. 9B

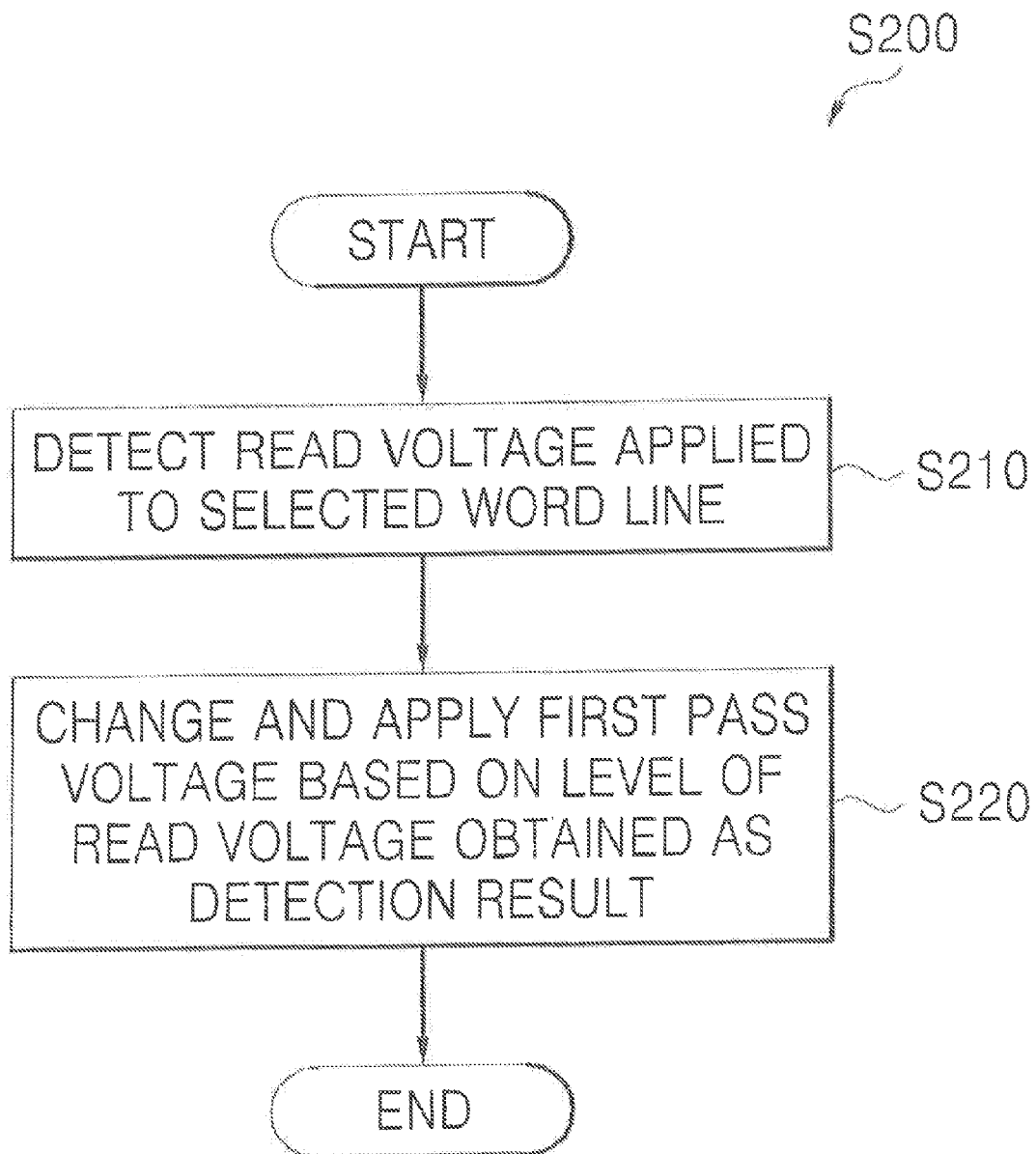


FIG. 10

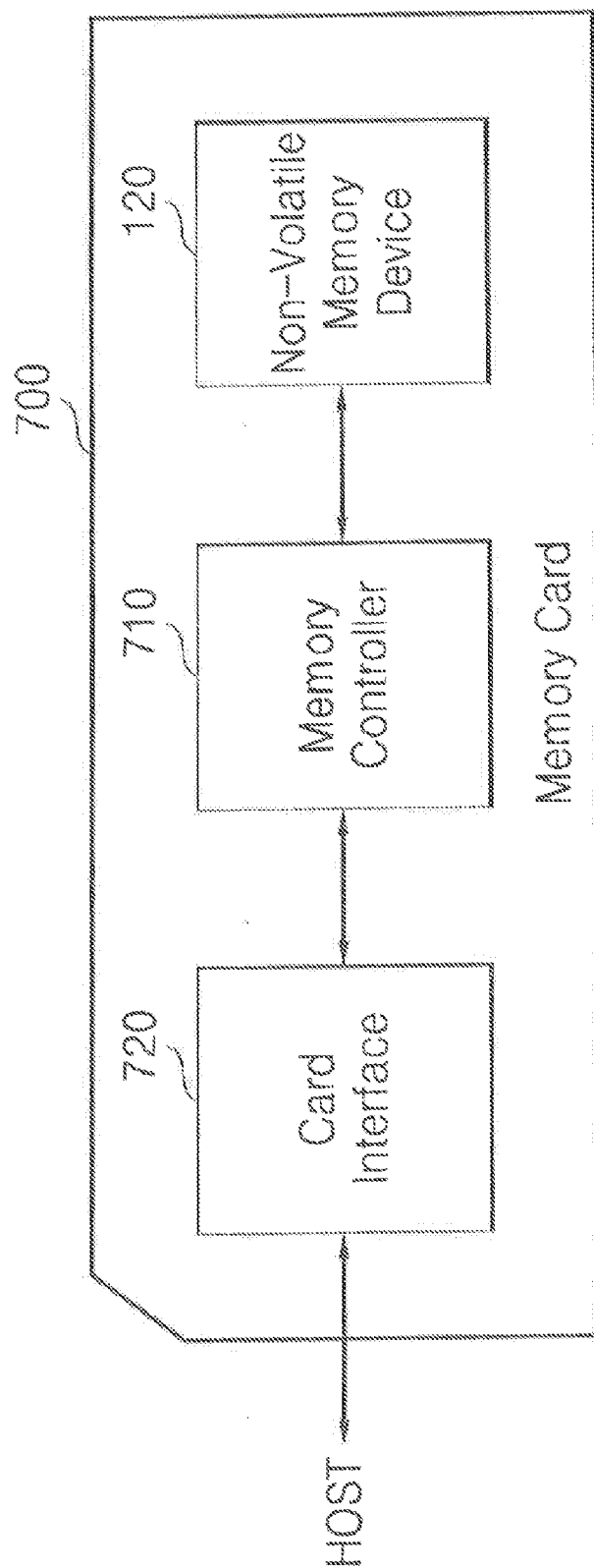


FIG. 11

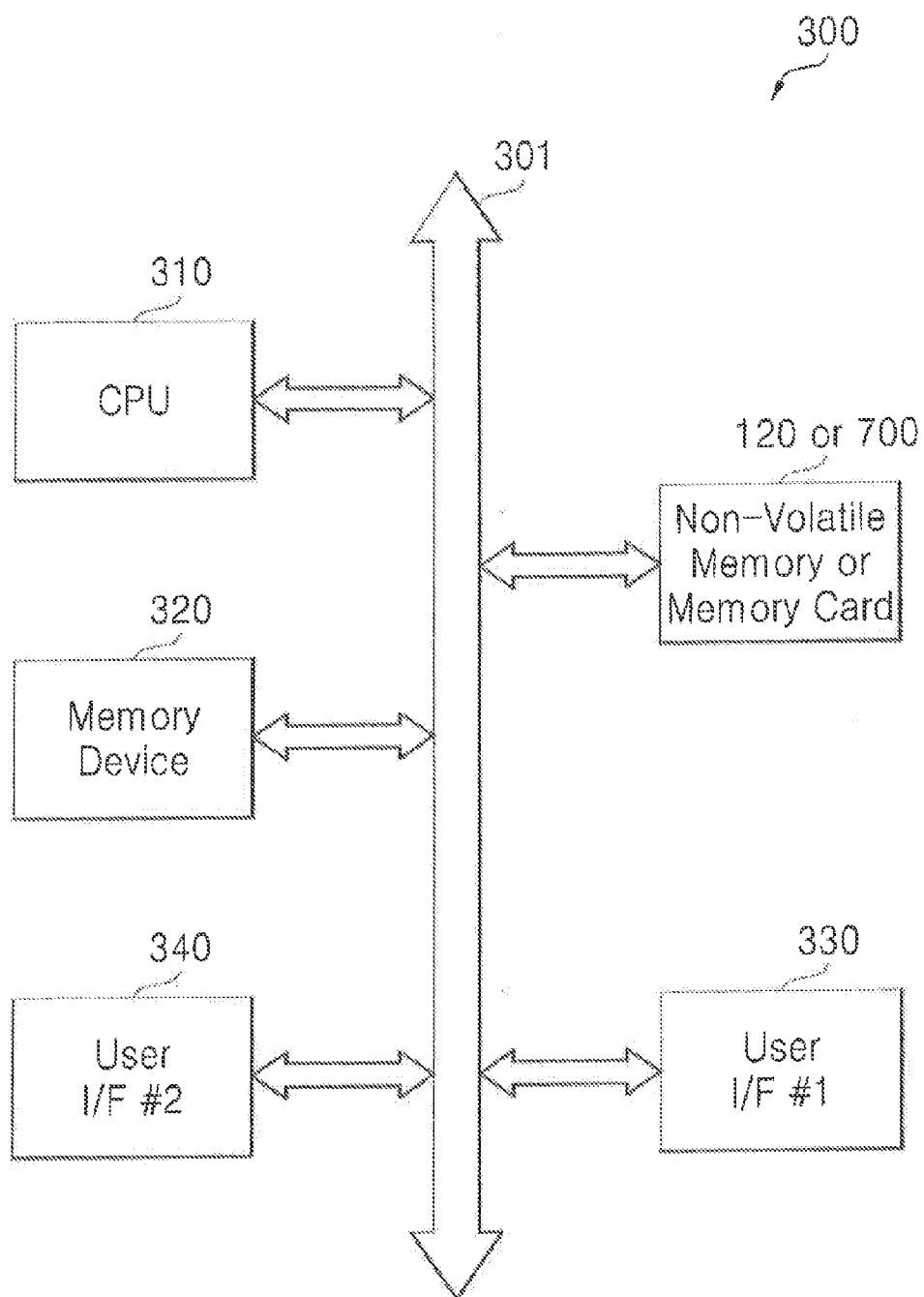


FIG. 12

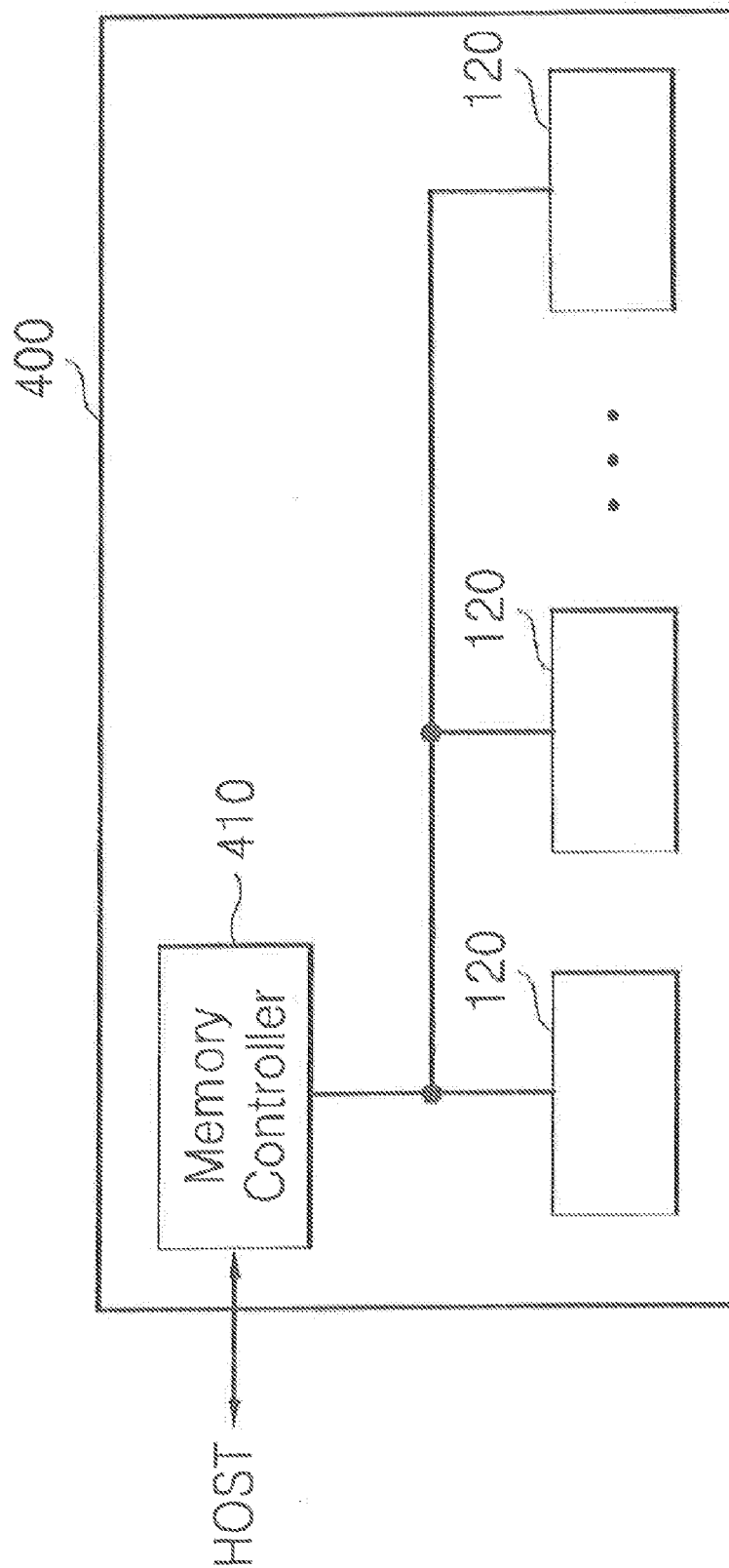
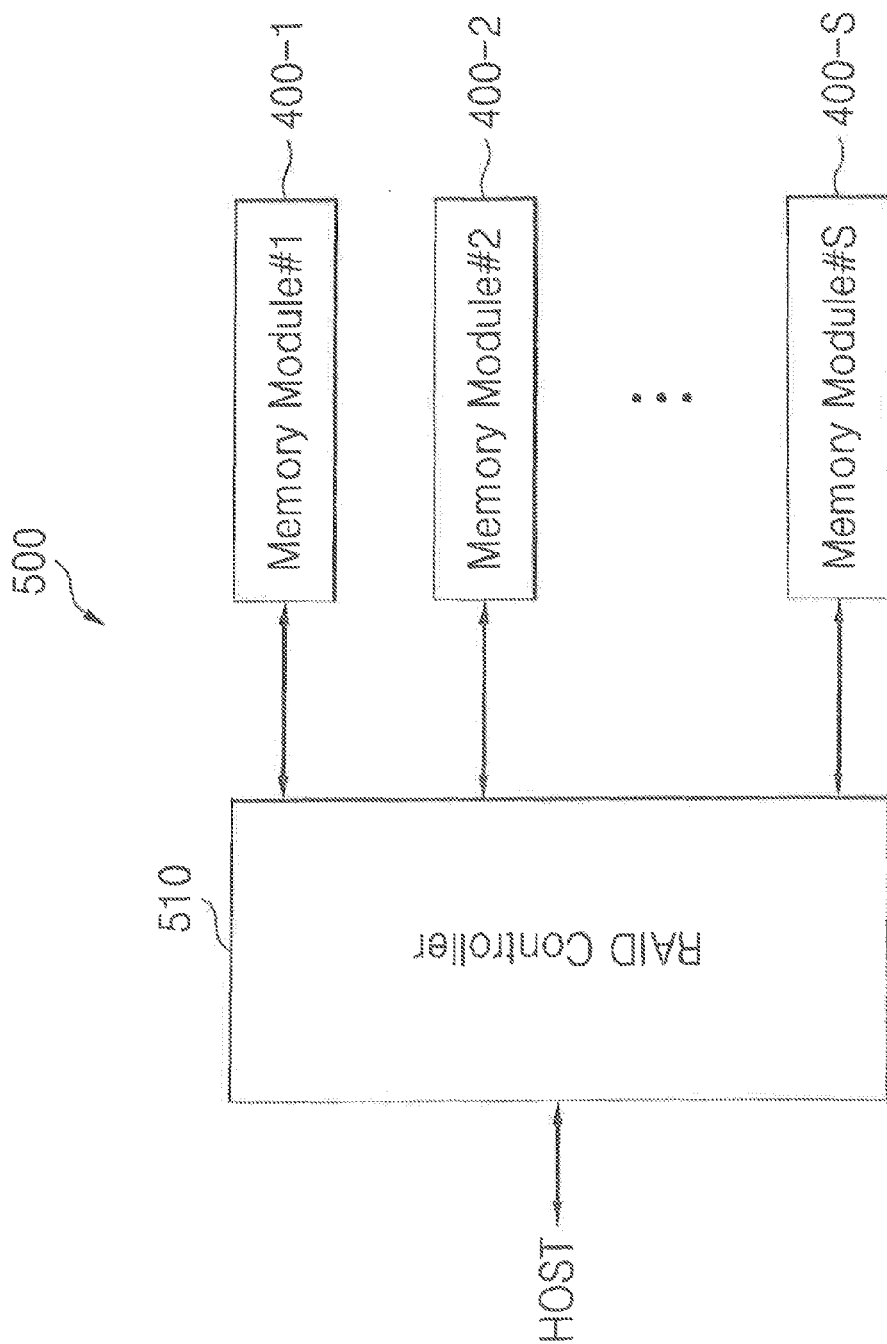


FIG. 13



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METHOD OF PROVIDING AN OPERATING VOLTAGE IN A MEMORY DEVICE AND A MEMORY CONTROLLER FOR THE MEMORY DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of U.S. Ser. No. 13/892,427 filed on May 13, 2013, which is a Continuation of U.S. application Ser. No. 13/289,282 filed on Nov. 4, 2011, issued as U.S. Pat. No. 8,441,856 on Apr. 24, 2013, which claims priority under 35 U.S.C. 119 to Korean Patent Application No. 10-2010-0112110 filed on Nov. 11, 2010, the disclosures of which are incorporated by reference herein in their entireties.

BACKGROUND OF THE INVENTIVE CONCEPT

1. Technical Field

The present inventive concept relates to a method of providing an operating voltage in a memory device and a memory controller, and more particularly to a method of controlling an operating voltage applied to an unselected word line in a memory device.

2. Discussion of the Related Art

After an erase/program operation is performed on a selected memory cell in a memory device, a trap charge occurs at an edge of a tunnel isolation layer in the memory transistor of the selected memory cell. The increase of the trap charge causes a decrease of memory cell current and an increase of the threshold voltage for turning the memory transistor of the selected memory cell ON. In other words, after the erase/program operation of the memory device, the threshold voltage of memory cells increases, expanding a threshold voltage distribution.

In a read operation, a read voltage V_{READ} is applied to a selected word line connected to a memory cell from which data will be read and a pass voltage V_{PASS} is applied to unselected word lines (i.e., word lines other than the selected word line) to turn ON memory cells connected to the unselected word lines.

At this time, when the threshold voltage of a memory cell is lower than that of adjacent memory cells, an electric field applied to a tunnel isolation layer of the memory cell having the lower threshold voltage is reduced by the memory cells having the higher threshold voltage.

As a result, the threshold voltage distribution of the memory cell having the lower threshold voltage is more expanded.

SUMMARY

Some embodiments of the present inventive concept provide a method of providing an operating voltage in a memory device, thereby improving the characteristic of the threshold voltage distribution of memory cells, and a memory controller.

According to some embodiments of the present inventive concept, there is provided a method of providing an operating voltage in a memory device. The method includes the steps of applying a read voltage to a selected word line; applying a first pass voltage to at least one word line among word lines adjacent to the selected word line; and applying a second pass voltage to word lines other than the selected word line and the

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at least one word line to which the first pass voltage is applied. The level of the first pass voltage may be higher than the level of the second pass voltage.

The steps of applying the first pass voltage may include changing the level of the first pass voltage and applying the first pass voltage at a different level according to the level of the read voltage.

The changing and applying the first pass voltage may include setting the level difference between the first pass voltage and the read voltage to a predetermined value.

The read voltage may include a verify read voltage used in incremental step pulse programming (ISPP) and a read voltage used in a read operation.

When the read voltage comprises a minus voltage, the changing and applying the first pass voltage may include applying the first pass voltage at different levels according to whether the read voltage is the minus voltage or not.

According to other embodiments of the present inventive concept, there is provided a memory device including a voltage generator configured to provide an operating voltage necessary for an operation of the memory device to a memory array; and a chip controller configured to control the voltage generator to apply a read voltage to a selected word line in the memory array, to apply a first pass voltage to at least one word line among unselected word lines adjacent to the selected word line, and to apply a second pass voltage to unselected word lines (other than the at least one word line to which the first pass voltage is applied). The level of the first pass voltage may be higher than the level of the second pass voltage.

The chip controller may control the voltage generator to change the level of the first pass voltage and apply the first pass voltage at a different level based on the level of the read voltage.

The chip controller may control the voltage generator to set the level difference between the first pass voltage and the read voltage to a predetermined value.

According to further embodiments of the present inventive concept, there is provided a memory system including a memory device; and a memory controller configured to control the memory device to apply a read voltage to a selected word line in the memory device, apply a first pass voltage to at least one word line among word lines adjacent to the selected word line, and apply a second pass voltage to word lines other than the selected word line and the at least one word line to which the first pass voltage is applied.

The memory device may include a memory array and a voltage generator configured to provide an operating voltage necessary for an operation of the memory device to the memory array based on control of the memory controller.

The present inventive concept now will be described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the inventive concept are shown. This inventive concept may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the inventive concept to those skilled in the art. In the drawings, the size and relative sizes of layers and regions may be exaggerated for clarity. Like numbers refer to like elements throughout.

It will be understood that when an element is referred to as being “connected” or “coupled” to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being “directly connected” or “directly coupled” to another element, there are no intervening elements present. As used herein, the term “and/or” includes any

and all combinations of one or more of the associated listed items and may be abbreviated as “/”.

It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first signal could be termed a second signal, and, similarly, a second signal could be termed a first signal without departing from the teachings of the disclosure.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the inventive concept. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features of the present inventive concept will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a block diagram of a non-volatile memory system according to some embodiments of the present inventive concept;

FIG. 2 is a circuit diagram of a NAND string of memory transistors in the memory cell array **231** of a non-volatile memory device according to some embodiments of the present inventive concept;

FIG. 3 is a threshold voltage distribution diagram showing an example of threshold voltage distributions of four logic states of the memory cells in the memory array **231** of the memory system of FIG. 1;

FIG. 4 is a cross sectional view of two adjacent memory transistors in the NAND string of FIG. 2;

FIG. 5 is a graph of threshold voltage ratios for explaining the effect of a memory system according to some embodiments of the present inventive concept;

FIG. 6 is a voltage diagram showing the different levels of pass voltages provided to unselected word lines adjacent to the currently selected word line in some embodiments of the present inventive concept;

FIG. 7 is a threshold voltage distribution diagram showing another example of threshold voltage distributions of the four logic states of memory cells in the memory array **231** of the memory system of FIG. 1;

FIG. 8 is a voltage diagram showing different pass voltages provided to unselected word lines adjacent to the selected word line so that the threshold voltage distribution states are as shown in FIG. 7, in other embodiments of the present inventive concept;

FIG. 9A is a flowchart of a method of providing an operating voltage in a semiconductor memory device according to some embodiments of the present inventive concept;

FIG. 9B is a flowchart detailing substeps of applying a first pass voltage in the method of FIG. 9A;

FIG. 10 is a block diagram of a memory card including the non-volatile memory device **120** shown in FIG. 1 according to an exemplary implementation of the memory system of FIG. 1;

FIG. 11 is a block diagram of a computer system including the non-volatile memory of FIG. 1 or FIG. 10 according to another exemplary implementation;

FIG. 12 is a block diagram of a memory system **400** implementing a solid state drive (SSD) and including the non-volatile memory device **120** shown in FIG. 1 according to still another exemplary implementation; and

FIG. 13 is a block diagram of a RAID array including a plurality of the memory system **400** of FIG. 12.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

FIG. 1 is a block diagram of a non-volatile memory system **100** according to some embodiments of the present inventive concept. The non-volatile memory system **100** includes a non-volatile memory device **120** and a memory controller **110** for controlling the non-volatile memory device **120**.

The non-volatile memory device **120** includes a memory cell array **230**, an address decoder **240**, a data write driver/sense amplifier (SA) circuit **250**, a chip controller **260**, a voltage generator **270**, and input/output (I/O) circuit **280**.

The memory controller **110** includes a static random access memory (SRAM) **111**, a central processing unit (CPU) **112**, a host interface (I/F) **113**, a control module **114**, and a memory I/F **115**.

The host I/F **113** includes an interface protocol to communicate with a host. The SRAM **111** stores data and/or a program in a volatile state. The memory I/F **115** interfaces with the non-volatile memory device **120**. The CPU **112** performs overall control of writing data to and/or reading data from the non-volatile memory device **120**.

The control module **114** controls the chip controller **260** to control the level of a first pass voltage applied to at least one word line adjacent to a selected word line based on the level of the read voltage applied to the selected word line. The chip controller **260** may directly or indirectly control the voltage generator **270** to change the level of the first pass voltage to a predetermined voltage level to be applied having the predetermined level to the at least one word line adjacent to the selected word line.

The memory cell array **230** includes a main area **231** and a spare area **232**. The main area **231** may be used to store user data and is thus referred to as a user data area. The spare area may be used to store error correcting code (ECC) data and the level of the read voltage.

The address decoder **240** selects one word line from among a plurality of word lines in response to a row address, and provides the read voltage to the selected word line, and provides the first pass voltage to at least one word line adjacent to the selected word line among unselected word lines, and provides a second pass voltage to the remaining unselected word lines. At this time, the first pass voltage may be equal to or higher than the second pass voltage. The read voltage may be a verify read voltage used in incremental step pulse programming (ISPP) or a read voltage used in a random access data read operation.

The write driver/SA circuit **250** is connected to a plurality of bit lines to program data into selected memory cells or to read data from the selected memory cells by sensing and amplifying the data. The write driver/SA circuit **250** may include a plurality of data storage cells (not shown) that input-buffer a data set to be programmed during a program operation and output-buffer a data set that has been read from memory cells during a read operation. Each of the data storage cells may include a plurality of latches. The data storage cells may also output-buffer a data set that has been read during a program verify operation.

A switching block (not shown) may also be provided between the write driver/SA circuit **250** and the memory cell array **230** to alternately connect the write driver and the SA to the bit lines.

The chip controller **260** outputs internal control signals (not shown) for controlling the operations (e.g., the program

operation, the erase operation, and the read operation) of the non-volatile memory device 120 in response to external commands. The voltage generator 270 generates operation voltages (e.g., a program voltage, a pass voltage, and a read voltage) necessary for the operations of the non-volatile memory device 120. The voltages generated by the voltage generator 270 may comprise a program operation voltage, a read operation voltage and a verify operation voltage.

The chip controller 260 controls the voltage generator 270 to change the level of the first pass voltage to the predetermined level and then provides the first pass voltage to at least one word line adjacent to the currently selected word line according to the control of the memory controller 110, but the present inventive concept is not restricted thereto. For instance, the chip controller 260 may control the voltage generator 270 to change the level of the first pass voltage to the predetermined level and then provide the first pass voltage to at least one word line adjacent to the selected word line, according to the control of the chip controller 260 and without the control of the memory controller 110.

The I/O circuit 280 interfaces with an external device, (e.g., the memory controller 110). The I/O circuit 280 may receive commands and the data to be programmed from the external device and may transmit a state signal and the data that has been read to the external device.

The memory controller 110 controls overall data exchange between the host and the non-volatile memory device 120. For instance, the memory controller 110 controls the non-volatile memory device 120 according to the control of the host to write data or read data.

FIG. 2 is a circuit diagram of a NAND string of memory transistors in the memory cell array 231 of the non-volatile memory device 120 according to some embodiments of the present inventive concept. FIG. 2 shows a single NAND string in the memory cell array 231.

Referring to FIG. 2, a read voltage V_{READ} output from the voltage generator 270 is provided to the currently selected word line WL_N among the plurality of word lines WL_0 through WL_m . A first pass voltage V_{pass} is provided to at least one word line among word lines WL_{N-1} and WL_{N+1} adjacent to the selected word line WL_N . A second pass voltage V_{pass} is provided to the remaining unselected word lines.

The level of the first pass voltage V_{pass} may be higher than the level of the second pass voltage V_{pass} , as will be described in detail with reference to FIG. 5 below.

A power supply voltage V_{cc} is applied to a string selection line SSL connected to the gate of a first selection transistor ST1. A ground voltage GND is applied to a ground selection line GSL connected to the gate of a second selection transistor ST2. A predetermined bias voltage V_{bias} is applied to a common source line CSL.

FIG. 3 is a threshold voltage distribution diagram showing an example of threshold voltage distribution states of the memory cells in the memory array 231 of the memory system of FIG. 1. FIG. 4 is a cross section of two adjacent memory transistors in the NAND string of FIG. 2 for explaining F-poly coupling occurring between memory cells.

Referring to FIG. 3, a multi-level cell (MLC), has four logic states, and each state has a threshold voltage distribution. FIG. 3, shows the threshold voltage distributions corresponding to a first logic state State1, a second logic state State2, a third logic state State3, and a fourth logic state State4. The threshold voltage distribution corresponding to each of the first through fourth logic states State1 through State4 is wider than desired, leaving a narrower margin between adjacent states, due to various causes. For instance,

the threshold voltage distribution may be wider due to coupling, e.g., F-poly coupling, between adjacent memory cells during programming.

Referring to FIG. 4, the first memory cell MCA is a memory cell that has been programmed to be in one of the first through fourth logic states State1 through State4 and the second memory cell MCB is a memory cell that will be programmed to be in one of the first through fourth logic states State1 through State4.

When the second memory cell MCB is programmed, charges are accumulated at a floating gate FG2 of the second memory cell MCB. At this time, the voltage potential of a floating gate FG1 of the first memory cell MCA adjacent to the second memory cell MCB may be increased due to coupling with the floating gate FG2 of the second memory cell MCB. Such an increased threshold voltage is still maintained by the coupling between the floating gates FG1 and FG2 even after the programming. Here, the second memory cell MCB may be any one of memory cells adjacent to the first memory cell MCA in a word line direction or in a bit line direction. The threshold voltage of the first memory cell MCA that has been programmed may be increased due to the coupling, and therefore, the threshold voltage distribution may be wider, and the threshold voltage value may be increased by more than one adjacent memory cells due to the randomness of the data programmed into adjacent memory cells. Consequently, a fail may occur in reading the first memory cell MCA.

FIG. 5 is a graph for explaining the effect in a memory system according to some embodiments of the present inventive concept. Referring to FIGS. 2 and 5, the first pass voltage V_{pass} higher than the second pass voltage V_{pass} is provided to a word line (e.g., WL_{N-1}) adjacent to the selected word line WL_N . For instance, when the second pass voltage V_{pass} is 7 V, the first pass voltage V_{pass} may be 8 V (i.e., higher than 7 V).

FIG. 5 shows a ratio

$$\frac{V_{th2}}{V_{th1}}$$

of the threshold voltage V_{th2} of a memory cell positioned at the selected word line WL_N to a threshold voltage V_{th1} of a memory cell positioned at the unselected word line WL_{N-1} adjacent to the selected word line WL_N as a function of the threshold voltage V_{th1} of the memory cell positioned at the unselected word line WL_{N-1} adjacent to the selected word line WL_N . In other words, the x-axis indicates the threshold voltage V_{th1} and the y-axis indicates

$$\frac{V_{th2}}{V_{th1}}$$

in FIG. 5. The ratio

$$\frac{V_{th2}}{V_{th1}}$$

is lower for all values of the threshold voltage V_{th1} when the first pass voltage V_{pass} is 8 V (curve 52) than when the first pass voltage V_{pass} is 7 V (curve 51).

Accordingly, it can be inferred that the threshold voltage of a memory cell positioned at the selected word line WL_N is less

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affected by coupling when the first pass voltage V_{pass} is 8 V than when the first pass voltage V_{pass} is 7 V.

FIG. 6 is a voltage diagram showing the different levels of pass voltages provided to unselected word lines adjacent to the currently selected word line in some embodiments of the present inventive concept.

Referring to FIGS. 3 and 6, the first pass voltage V_{pass} is applied to the unselected word lines adjacent to the selected word line at different levels. For instance, when a first read voltage V_{RD1} is applied to the selected word line, the first pass voltage V_{pass} may be 8.5 V. When a second read voltage V_{RD2} is applied to the selected word line, the first pass voltage V_{pass} may be 8 V. When a third read voltage V_{RD3} is applied to the selected word line, the first pass voltage V_{pass} may be 7.5 V.

At this time, the level difference V_s between the different values of the first pass voltage V_{pass} may have a predetermined constant difference value and is 0.5 V in FIG. 6.

As described above, when the first pass voltage V_{pass} is applied at different levels according to the level of a read voltage, a read disturb problem can be mitigated.

FIG. 7 is a threshold voltage distribution diagram showing different threshold voltage distributions of the four logic states of the MLC memory cells in the memory array 231 of the memory system of FIG. 1. FIG. 8 is a voltage diagram showing different pass voltages provided to unselected word lines adjacent to the currently selected word line when the threshold voltage distribution of logic states are as shown in FIG. 7, in other embodiments of the present inventive concept.

Referring to FIGS. 7 and 8, the first state State1 having the threshold voltage distribution shown in FIG. 7 has a negative threshold voltage unlike the example shown in FIG. 3.

At this time, the threshold voltage distribution of logic states may be divided into the first state State1 having the negative threshold voltage and the other states, i.e., the second through fourth state State2 through State4 having positive threshold voltages. In this case, when a fourth read voltage V_{RD4} is applied to read the first state State1, the first pass voltage V_{pass} may be 8.5 V; otherwise, the first pass voltage V_{pass} may be 7.5 V.

At this time, the level difference V_s in the first pass voltage V_{pass} may have a predetermined constant difference value and is 1 V in FIG. 8.

FIG. 9A is a flowchart of a method of providing an operating voltage in a semiconductor memory device according to some embodiments of the present inventive concept.

Referring to FIG. 9A, a read voltage is applied to a selected word line in step S100. At this time, the read voltage may be a verify read voltage used in ISPP or a read voltage used in a random data access read operation.

A first pass voltage is applied to at least one of word lines adjacent to the selected word line in step S200. A second pass voltage is applied to the remaining word lines other than the selected word line and the at least one word line to which the first pass voltage is applied in step S300. The first pass voltage may be equal to or higher than the second pass voltage. The steps S100, S200, and S300 may be commenced sequentially (one step commenced after the prior has been commenced) or alternately may be commenced in parallel (commenced at substantially the same time). In practice the first pass voltage is applied to at least one of the unselected word lines adjacent to the selected word line (in step S200) while the second pass voltage is applied to the remaining unselected word lines (in step S300) while the read voltage is applied to the selected word line (in step S100).

FIG. 9B is a flowchart detailing substeps of step S200 in the method of FIG. 9A. Referring to FIG. 1 and FIGS. 9A and 9B,

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in step S210, the non-volatile memory device 120 detects or identifies the read voltage applied to the selected word line according to the control of the memory controller 110 or the chip controller 260. In step S220, the non-volatile memory device 120 changes and applies the first pass voltage based on the level of the read voltage obtained as a result of the detection or identification. For instance, as the level of the read voltage is higher, the non-volatile memory device 120 may apply the first pass voltage which is lower or higher. The level difference (increment V_s) in the first pass voltage may have a predetermined constant value.

FIG. 10 is a block diagram of a memory card including the non-volatile memory device 120 shown in FIG. 1 according to an exemplary implementation of the memory system of FIG. 1. The memory card 700 shown in FIG. 10 is implemented as a flash memory card. The memory card 700 may include non-volatile memory device 120 that can control the operating voltages applied to the selected and adjacent unselected word lines as explained above, a memory controller 710, and a card interface 720 to interface with a host.

The memory controller 710 controls data transmission between the non-volatile memory device 120 and the card interface 720.

In some exemplary implementations, the memory card 700 of FIG. 10 may be implemented as a smart card.

According to an exemplary implementation, the card interface 720 may be a secure digital (SD) card interface or a multi-media card (MMC) interface. However, implementation are not limited thereto. The card interface 720 may interface for data exchange between the host and the memory controller 710 according to a communication protocol.

When the memory card 700 is connected to a host, e.g., a PC, a tablet PC, a digital camera, a digital audio player, a cellular phone, a console video game hardware, a digital set-top box, and so forth, the memory controller 710 of the memory card 700 may transmit or receive data stored in the non-volatile memory device 120 with the host.

FIG. 11 illustrates a block diagram of a memory system 300 including the non-volatile memory device 120 shown in FIG. 1 or the memory card 700 of FIG. 10 according to various other exemplary embodiments.

Referring to FIG. 11, the memory system 300 may be implemented in the form of a cellular phone, a smart phone, a PDA (personal digital assistant), a digital camera, a portable game console, a MP3 player, a HDTV (High-definition television), a GPS (Global Positioning System), a navigator, a CE (consumer equipment), a digital settop box or an IT (information technology) device.

The memory system 300 may include a CPU 310 and a non-volatile memory device 120 which are connected with each other through a system bus 301. According to another exemplary embodiment, the memory system 300 may include the CPU 310 and the memory card 700 of FIG. 10, which are connected with each other through the system bus 301.

The CPU 310 may control operations of the non-volatile memory device 120, e.g., a program operation, a read operation, an erase operation or an operation of transmitting data to the host. Alternatively, the memory controller 710 of the memory card 700 may control operations of the non-volatile memory device 120, e.g., a program operation, a read operation, an erase operation or an operation of transmitting data to the host.

The memory device 320 connected to the bus 301 may be used as the random access system memory (RAM) of the CPU 310. The memory device 320 may be a DRAM, or a SRAM. The memory device 320 may be a memory module e.g., a SIMM (single in-line memory module) or a DIMM

(dual in-line memory module). In alternative embodiments, the memory device **320** may be a memory module that includes a plurality of the non-volatile memory device **120** illustrated in FIG. **1**.

The memory system **300** may include a first user interface **330** such as a display or a touch pad. And, the memory system **300** may further include a second user interface **340** such as an input/output interface. The second user interface **340** may be an output device such as a printer or an input device such as a keyboard or a mouse. According to an exemplary embodiment, the first user interface **330** may be replaced with a CMOS image sensor. The CMOS image sensor may convert an optical image to a digital image, and the digital image will be stored in the memory device **120** (or the memory card **700**) under control of the CPU **310**.

FIG. **12** is a block diagram of a memory system **400** implementing a solid state drive (SSD) and including the non-volatile memory device **120** shown in FIG. **1** according to still another exemplary implementation. Referring to FIG. **12**, the memory system **400** implements a solid state drive (SSD).

The memory system **400** may include a plurality of non-volatile memory devices **120** and a memory controller **410** controlling the data access functions of each of the plurality of non-volatile memory devices **120**. Each of the plurality of non-volatile memory devices **120**, under the control of the memory controller **410**, can adaptively control access functions to determine or verify whether a selected non-volatile memory cell among a plurality of non-volatile memory cells included in each of the plurality of non-volatile memory devices **120** is programmed or erased.

FIG. **13** is a block diagram of a RAID array including a plurality of the memory system **400** of FIG. **12**. Referring to FIGS. **12** and **13**, a RAID array **500** may be a redundant array of independent disks (RAID) system that includes a RAID controller **510** and a plurality of memory systems **400-1** to **400-S** of FIG. **12**, where S is a natural number.

Each of the plurality of memory systems **400-1** to **400-S** may alternatively be a memory card **700** of FIG. **10**. The plurality of memory systems **400-1** to **400-S** may compose a RAID array having a user selected redundancy level (RAID level). Each of the plurality of memory systems **400-1** to **400-S** includes one of the memory controller **410** of FIG. **12** to control the function of the plurality of the non-volatile memory devices **120** therein. The RAID controller **510** controls the function of the plurality of memory systems **400-1** to **400-S**. The RAID array **500** may be included in a personal computer (PC) or in one SSD unit for use therein.

During a write (or program) operation, the RAID controller **510** outputs a write (or program) data output command from the host to one or more of the plurality of memory systems **400-1** to **400-S** according to a selected one of a plurality of RAID levels in response to a write (or program) command output from the host.

Additionally, during a read operation, the RAID controller **510** may transmit data read from one or more of the plurality of memory systems **400-1** to **400-S** to the host according to the selected one of a plurality of RAID levels in response to a read command output from the host.

The present inventive concept may be implemented with hardware such as modules, or software such as algorithm or firmware. The algorithm or firmware may be implemented as computer readable codes and/or programs on a computer readable recording medium. The method of providing an operating voltage in a semiconductor memory device according to some embodiments may be implemented by executing the computer program for executing the method of providing

an operating voltage in a semiconductor memory device stored in the computer readable recording medium.

The computer readable recording medium is any data storage device that can store data which can be thereafter read by a computer system. More particularly, the computer readable recording medium may be, e.g., a tangible, non-transitory recording medium. Examples of the computer readable recording medium include read-only memory (ROM), random-access memory (RAM), CD-ROMs, magnetic tapes, floppy disks, and optical data storage devices. The program codes for executing a method of upgrading an operation program in an RFID system may be transmitted in the form of carrier waves (such as data transmission through the Internet).

The computer readable recording medium can also be distributed over network coupled computer systems so that the computer readable code is stored and/or executed in a distributed fashion. Also, functional programs, codes, and/or code segments for realizing embodiments can be easily construed by programmers skilled in the art to which the embodiments pertain.

As described above, according to some embodiments of the present inventive concept, the characteristic of the threshold voltage distribution of the logic states of multilevel memory cells (MLCs) is improved.

Exemplary embodiments have been disclosed herein, and although specific terms are employed, they are used and are to be interpreted in a generic and descriptive sense only and not for purpose of limitation. In some instances it would be apparent to one of ordinary skill in the art viewing of the present application, that features, characteristics, and/or elements described in connection with a particular embodiment may be used singly or in combination with features, characteristics, and/or elements described in connection with other embodiments unless otherwise specifically indicated. Accordingly, it will be understood by those of skill in the art viewing of the present application that various changes in form and details may be made without departing from the spirit and scope of the present inventive concept as set forth in the following claims.

What is claimed is:

1. A method of reading a nonvolatile memory device, comprising:
 - applying a first read voltage to a selected word line connected to memory cells of the nonvolatile memory device;
 - applying a first pass voltage to a first unselected word line, the first unselected word line being adjacent to the selected word line while the first read voltage is applied to the selected word line;
 - applying a second pass voltage to at least one of remaining unselected word lines other than the first unselected word line while the first read voltage is applied to the selected word line, the second pass voltage being less than the first pass voltage;
 - applying a second read voltage to the selected word line connected to the memory cells of the nonvolatile memory device, the second read voltage being less than the first read voltage;
 - applying a third pass voltage to the first unselected word line while the second read voltage is applied to the selected word line, the third pass voltage being different from the first pass voltage; and
 - applying a fourth pass voltage to the at least one of the remaining unselected word lines other than the first unselected word line while the second read voltage is

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applied to the selected word line, the fourth pass voltage being substantially the same as the second pass voltage, wherein the first unselected word line and a string select line are in the same side relative to the selected word line.

2. The method of claim 1, wherein a first data is read from the memory cells during applying the first read voltage to the selected word line, and a second data is read from the memory cells during applying the second read voltage to the selected word line, data bits of a first page are generated from the first data and the second data.

3. The method of claim 1, wherein the applying the first read voltage to the selected word line, the applying the first pass voltage to the first unselected word line and the applying the second pass voltage to at least one of the remaining unselected word lines are performed concurrently.

4. The method of claim 1, wherein the applying the second read voltage to the selected word line, the applying the third pass voltage to the first unselected word line and the applying the fourth pass voltage to the at least one of the remaining unselected word lines are performed concurrently.

5. The method of claim 1, wherein the applying the second read voltage to the selected word line is performed after the applying the first read voltage to the selected word line is performed.

6. The method of claim 1, wherein the first pass voltage is determined based on the first read voltage, and the third pass voltage is determined based on the second read voltage.

7. The method of claim 1, wherein the second pass voltage is applied to all of the remaining unselected word lines that are not adjacent to the selected word line, and

the fourth pass voltage is applied to all of the remaining unselected word lines that are not adjacent to the selected word line.

8. The method of claim 1, wherein a difference between the first read voltage and the second read voltage is greater than a difference between the first pass voltage and the third pass voltage.

9. The method of claim 1, wherein a difference between the first read voltage and the second read voltage is less than a difference between the first pass voltage and the third pass voltage.

10. The method of claim 1, wherein the third pass voltage is less than the first pass voltage.

11. A method of reading a nonvolatile memory device, comprising:

applying a first read voltage to a selected word line connected to memory cells of the nonvolatile memory device;

applying a first pass voltage to a first unselected word line while the first read voltage is applied to the selected word line, the first unselected word line being adjacent to the selected word line;

applying a second pass voltage to a second unselected word line while the first read voltage is applied to the selected word line, the second unselected word line being adjacent to the selected word line;

applying a third pass voltage to remaining unselected word lines other than the first unselected word line and the second unselected word line while the first read voltage is applied to the selected word line, the third pass voltage being less than the first pass voltage;

applying a second read voltage to the selected word line connected to the memory cells of the nonvolatile memory device, the second read voltage being less than the first read voltage;

applying a fourth pass voltage to the first unselected word line while the second read voltage is applied to the

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selected word line, the fourth pass voltage being substantially the same as the first pass voltage;

applying a fifth pass voltage to the second unselected word line while the second read voltage is applied to the selected word line, the fifth pass voltage being less than the second pass voltage; and

applying a sixth pass voltage to the remaining unselected word lines other than the first unselected word line and the second unselected word line while the second read voltage is applied to the selected word line, the sixth pass voltage being substantially the same as the third pass voltage.

12. The method of claim 11, wherein the first pass voltage is substantially the same as the second pass voltage.

13. The method of claim 11, wherein the fifth pass voltage is less than the sixth pass voltage.

14. The method of claim 11, wherein the first unselected word line and a ground select line are in the same side relative to the selected word line, and

the second unselected word line and a string select line are in the same side relative to the selected word line.

15. The method of claim 11, wherein a difference between the first read voltage and the second read voltage is greater than a difference between the second pass voltage and the fifth pass voltage.

16. The method of claim 11, wherein a difference between the first read voltage and the second read voltage is less than a difference between the second pass voltage and the fifth pass voltage.

17. A method of reading a nonvolatile memory device, comprising:

applying a first read voltage to a selected word line connected to memory cells of the nonvolatile memory device;

applying a first pass voltage to a first unselected word line while the first read voltage is applied to the selected word line, the first unselected word line being adjacent to the selected word line;

applying a second pass voltage to at least one of remaining unselected word lines other than the first unselected word line while the first read voltage is applied to the selected word line, the second pass voltage being less than the first pass voltage;

applying a second read voltage to the selected word line connected to the memory cells of the nonvolatile memory device, the second read voltage being less than the first read voltage;

applying a third pass voltage to the first unselected word line while the second read voltage is applied to the selected word line, the third pass voltage being different from the first pass voltage; and

applying a fourth pass voltage to the at least one of the remaining unselected word lines other than the first unselected word line while the second read voltage is applied to the selected word line.

18. The method of claim 17, wherein the fourth pass voltage is substantially the same as the second pass voltage.

19. The method of claim 17, wherein the third pass voltage is less than the first pass voltage.

20. The method of claim 17, wherein the second pass voltage is applied to all of the remaining unselected word lines that are not adjacent to the selected word line, and the fourth pass voltage is applied to all of the remaining unselected word lines that are not adjacent to the selected word line.

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